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NOTE ON LOW-LEVEL AIRBORNE OBSERVATIONS OF TEMPERATURE NEAR PRAIRIE OASES

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The following is a description of a pilot study of oasis effects in southern Alberta using an instrumented aircraft. Observations were taken over two, large irregular prairie lakes and over an irrigated project to test the hypothesis that important climatic modifications, measurable only from an airborne platform, occur in this region over and near such surface features. The data taken in this study are insufficient to apply to boundary-layer theory, and no attempt is made to explain the disposition of energy in the region studied. The intent is only to present a brief three-dimensional picture of some observed phenomena near three small prairie oases. Lenschow (1965) and Lenschow and Dutton (1964) have discussed the advantages of using aircraft in studies of this nature and have presented a detailed review of boundary-layer theory as applied to aircraft observations. They refer to several other studies in this field.

Instrumented aircraft have been used for many years to obtain area measurements, particularly in the fields of cloud physics and weather modifications. In the research described in this paper, two, light, single-engine aircraft were used—a Cherokee 140 and a Cherokee 6. Instruments used to measure air temperature consisted of an electrical resistance element and a five-junction copper-constantan thermopile. One end of the thermopile was potted in oil within a frigistor at 0°C. The elements, housings, and aircraft mountings were in-house designed so that radiation and dynamic heating effects were negligible. At 120-kt airspeed, the time constant was approximately 0.5 sec. The electrical resistance sensor was calibrated in a water bath to be accurate to 0.1°C. Readings were taken by a technician using a milliammeter; in later stages of the observations, a strip chart recorder was used. The recorder was powered by an inverter driven by the aircraft's 12-v DC supply. A radiation thermometer (Barnes IT-3) was mounted in the cabin in such a way that the sensing head "looked" through a hole in the floor of the aircraft. The thermometer was powered from the inverter in the cabin. The Cherokee-6 instrumentation, sensors, sensor mountings, data acquisition system, and power supplies will be completely described in a subsequent publication. The temperature resistance element and mounting used on the Cherokee 140 are shown in figure 1.

The general observational procedure required that the aircraft be flown at a height of 15 and 45 m above the study surface. Ground surface and air temperatures were associated with ground fixes for position reference. Transections over the area of interest were flown at various horizontal and vertical intervals. For example, measurements were taken at one level from north to south; then the altitude was increased to the next observational level and measurements were taken from south to north over the same ground track. The ground track was then horizontally displaced the appropriate amount, and similar measurements were made at the appropriate altitudes.

The ground tracks for the surface infrared temperature measurements were chosen for each situation to cover representative surfaces around and on the feature being studied, with no correction applied for surface emissivity. Previous work by the author over agricultural and non-agricultural land suggests that the IR measurements are accurate to ± 2.0°C, and temperature differences are accurate to ± 0.5°C when observations were taken at an altitude less than 300 m. At this level and in this study area, atmospheric moisture effects were found to be negligible.

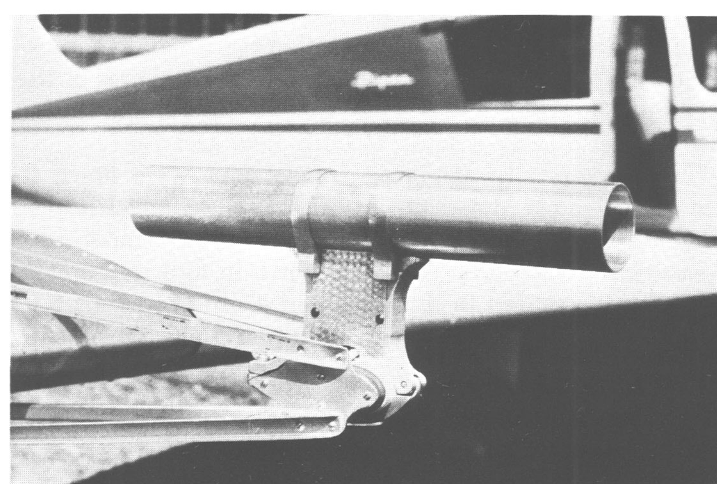

FIGURE 1.—Air temperature sensor, housing, and mounting used on a Cherokee 140 near the wingtip. Aluminum tube is standard 2 in. in diameter and 40 cm long and contains the electrical resistance elements. The vertical section below the tube contains electrical connectors.

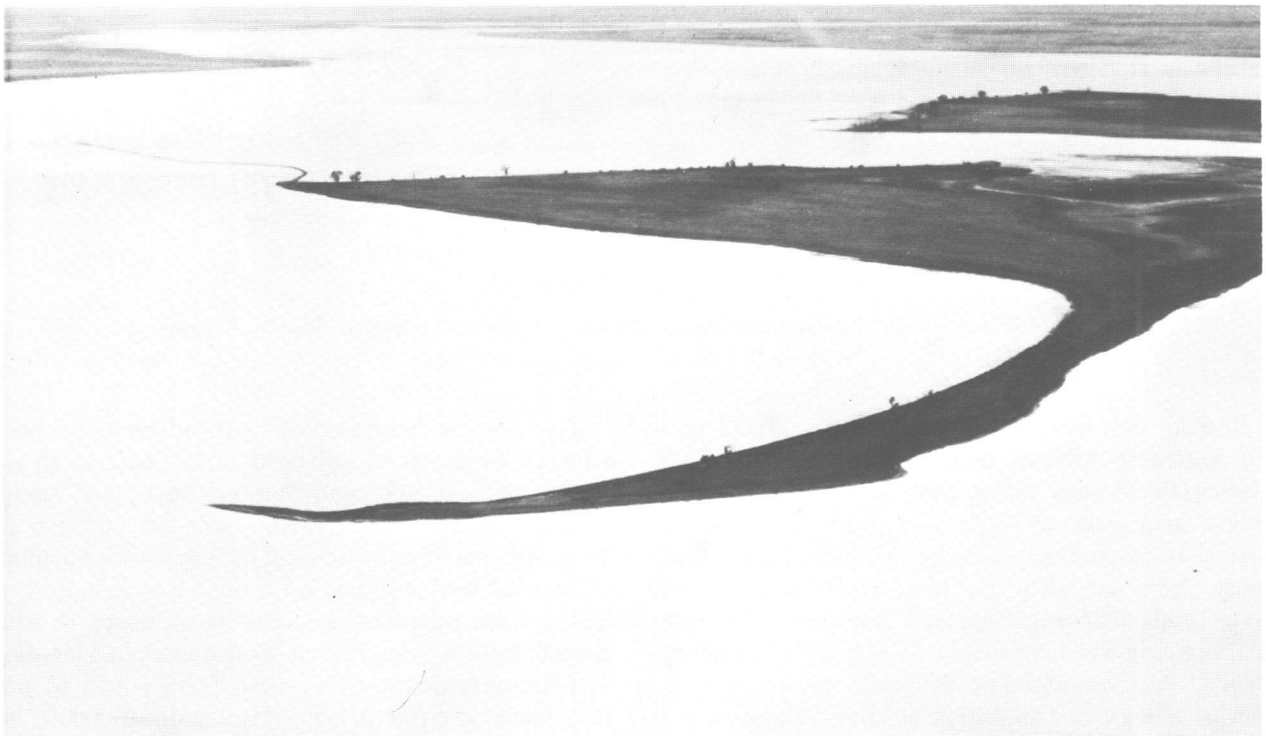

FIGURE 2.—Lake Pakowki, Alberta, looking south. The body of land and curved spit are part of the center island. Strong surface heating was noted over the islands in the lake and inland from the western shore. A strong oasis developed over the lake on many observational days.

Lake Pakowki is the remnant of a large Pleistocene glacial lake situated in southeastern Alberta. It is shallow with a widely fluctuating annual water level (average depth less than 3.2 m), nearly always turbid, and high in alkali salts. The surrounding terrain is composed of dryland farms to the south, west, and north, and rangeland reaching to the east. In general, the surrounding surface is flat and dry for most of the summer (spring and summer rainfall comes mostly from convection storms and averages 5.1 cm). Figure 2 illustrates some essential features of the lake, and figures 3 and 4 show the size and shape during late July and early August of both 1966 and 1967.

Ten horizontally displaced transections were flown in the north-south direction at 15- and 45-m altitudes. Therefore, the horizontal extent of air-temperature measurements covered the area shown in figures 3 and 4. The data presented in figures 3 and 4 are the average of 3 hr of observations between 1200 and 1500 hr, Aug. 3, 1967. The isotherms and temperature grid (points at which temperatures were observed) represent temperature differences in °C between the indicated position and the ambient prairie air 14–16 km upwind at the same elevation above the surface. Wind speed and direction were measured at a 15-m height, 15 km upwind. Each set of temperatures measured at 15 and 45 m above the lake was followed by measurement of upwind air temperature at 15 and 45 m above the ground. Generally, it was found that ambient prairie air temperature varied very little with time. A superadiabatic (unstable) lapse existed during the study period over the area and time indicated. Air temperatures at 2 m varied with surface characteristics. At the upwind measuring point, the air temperature near the surface (2 m) was 31.5°C to 33.5°C during the study period. On the day shown, the variation with time was 24.7°C to 23.6°C from 1200 to 1500 hr at 15 m, and 23.6°C to 22.9°C over the same period at a 45-m altitude. The Student's "t" test was used to determine the significance of the temperature differences shown in the figures. The values are significant at the 1-percent level. When the values are not significant at the 5-percent level, a small letter "o" is placed at the position where the measurement was taken.

The effect of the lake on the temperature of the air passing over it was noted at both levels, with maximum cooling of 3°C at 15 m and 2°C at a 45-m height. At 75 m there was no measurable effect on this particular day. On other calmer days, 3°C cooling was noted up to 120 m, but the effect was more restricted horizontally. The isotherms and temperature grid in figures 3 and 4 show the average position of the cold and warm air "parcels" for the 3-hr period shown. Figure 5 presents the surface radiation temperature over the ground track indicated in figures 3 and 4, at three time periods, and shows the high surface temperature of the islands and area to the west of the lake.

It is somewhat surprising that the regions of cool temperatures at 15 and 45 m are almost entirely displaced from the lake. The region of coolest temperature on the lee

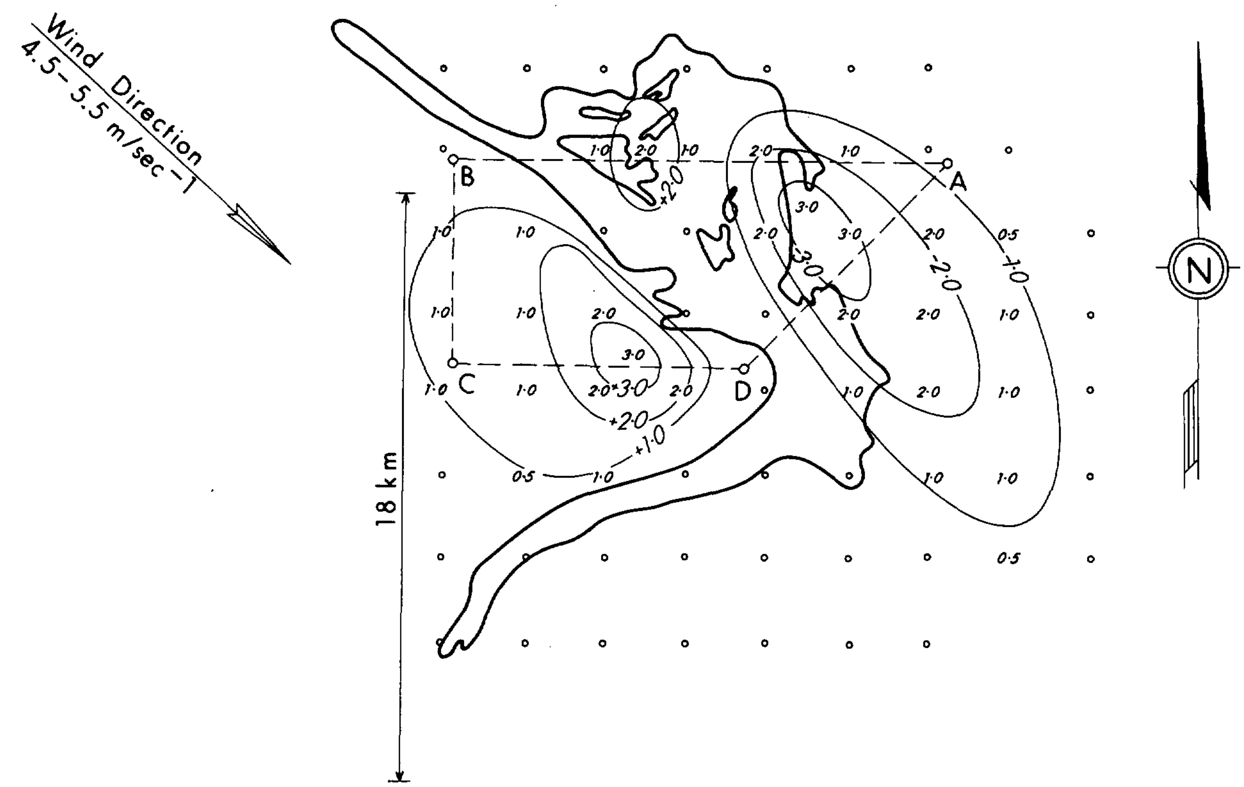

FIGURE 3.—Isotherms and temperature grid of average air temperature difference (°C) bewteen the position indicated at 15 m and the ambient prairie air 14–16 km upwind, at 15 m above the surface near Lake Pakowki, Alberta, on Aug. 3, 1967, for the period 1200–1500 hr (lat. 49°20′ N., long. 110°50′ W.).

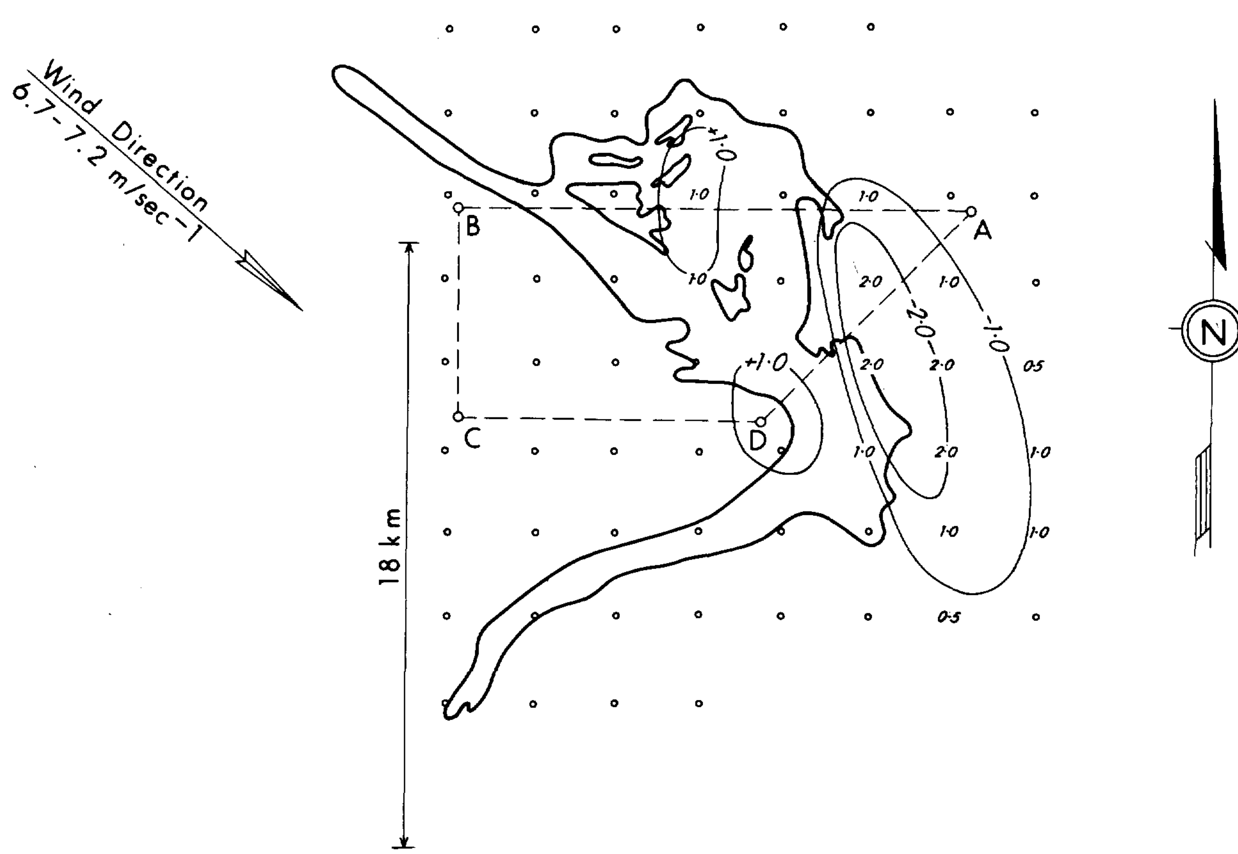

FIGURE 4.—Isotherms and temperature grid of average air temperature difference (°C) between the position indicated at 45 m and ambient prairie air 14–16 km upwind, at 45 m above the surface near Lake Pakowki, Alberta, on Aug. 3, 1967, for the period 1200–1500 hr (lat. 49°20′ N., long. 110°50′ W.).

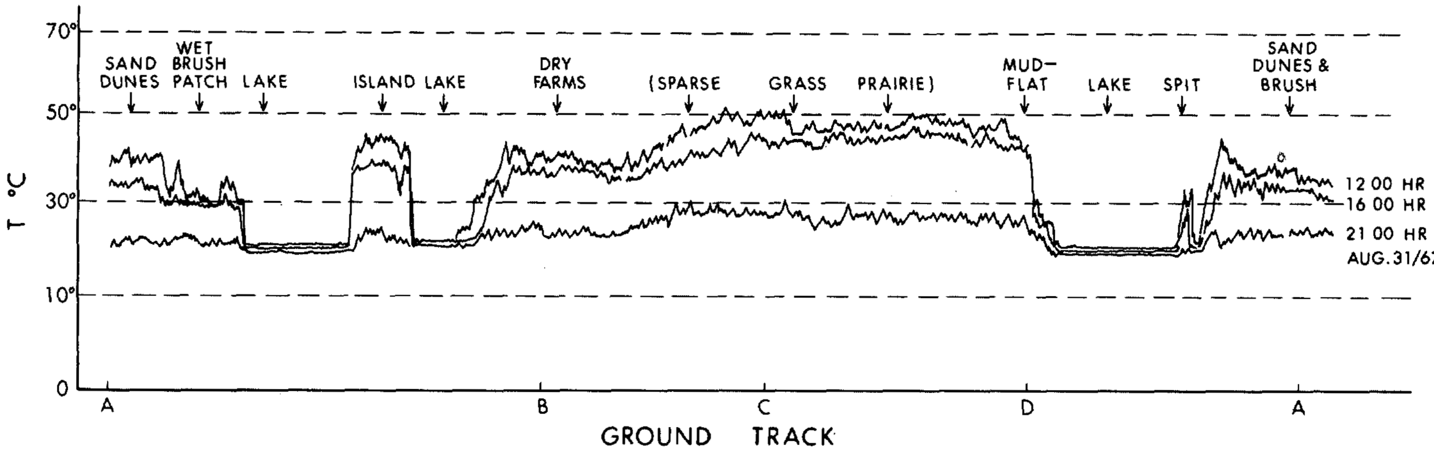

FIGURE 5.—Surface radiation temperature (°C) at three intervals over ground track ABCD of Lake Pakowki shown in figures 3 and 4.

shore does not extend over the shore exposed to the largest fetch. Doubtless, lateral mixing from the heated shoreline over this narrow water fetch would tend to place the coolest air to the north of the longest fetch. During the study period and also during August of 1966 and 1967 when transects were flown over the lake, it was discovered that the shape and position of the cooled air were highly variable and largely a function of daytime heating, wind speed, and direction. The data presented show the *average* position of the cooled air during the study period. The author is unable to explain adequately why the position should be displaced to the lee as much as shown. At no time was cooling noticed at altitudes of more than 120 m above the terrain, and at no time was cooling measurable farther than 11 km from the lee edge of the lake. There were many days when no air cooling was measurable regardless of height or position.

The reproduced traces of surface radiation temperature (fig. 5) show temperature variation with time of day. The transect was flown at 75 m over the track ABCDA. Observations were discontinued at 2100 hr because darkness obscured the ground track. The rapid cooling of the soil surface compared with the lake was evident as the day progressed. The area of land over the track BCD (fig. 5) had a very high surface radiation temperature (occasionally in excess of 50°C) compared to the agricultural surface upwind, which was 34° to 39°C. These traces emphasize the temperature discontinuity between the lake and surrounding prairie.

A second lake was studied on Aug. 20, 1957, for a possible oasis effect. Lake Murray, in southern Alberta, is surrounded by dry farmland. The terrain is essentially flat prairie with occasional wetland patches. Aircraft transects were flown at 15 and 45 m above the surface and air temperature was observed in a manner similar to that used over Lake Pakowki. The measurements indicated an exceedingly complex situation, and it was not possible to relate the position of cooled air parcels to the amount of cooling. Most of the occurrences of cooled air parcels were over the lee edge of the lake, and at no time was cooled air measurable over the land.

Lake Murray is somewhat smaller than Lake Pakowki and the lack of larger, definable regions of cooled air over Lake Murray can be partially explained on this basis. Because of the smaller size, warm air advected from the surrounding land would be apt to invade the cooled air of the lake area and persist as parcels. This would create a complex situation as noted above. Over larger lakes there would be less opportunity for warm air to persist because air cooled by the lake is more likely to exist as a larger mass. Other transects were flown on Aug. 20, 1967, at a constant altitude of 240 m above the lake surface to measure surface radiation temperature throughout 1 day and night. The ground track was maintained through the dark hours by using the Medicine Hat VOR Radio Station. These data are shown in figure 6.

As with the Lake Pakowki readings, these observations show the marked surface temperature discontinuities and difference in rate of cooling between the lake and soil surface. At 0430 hr there is little difference between the average lake and soil surface temperature. The peninsula at ground track position B was cooler by approximately 4°C than the lake at 0430 hr. Floating marsh weeds and algae may cause the water surface temperature fluctuations. Fields of fallow, forage, and irrigated stubble may be noted near ground track position D. The fallow was approximately 47°C, and warmer by approximately 6°C during the day than the forage, which in turn was approximately 5°C warmer than irrigated stubble. As nocturnal cooling proceeded, the fallow temperature was reduced to approximately 17°C. The forage was warmer at approximately 20°C, and the irrigated stubble was at about 25°C. This order did not always hold, however.

A small irrigation project of about 12 sq km situated at the confluence of the Bow and Old Man Rivers, Alberta, was studied with techniques similar to those used at Lake Pakowki. The results of measurements of air and surface radiation temperature are shown in figures 7, 8, and 9, with observational altitudes of 15 and 45 m above average ground surface. Data were taken in a manner similar to that used over Lake Pakowki, except that transects were displaced horizontally to cover the area as indicated. The

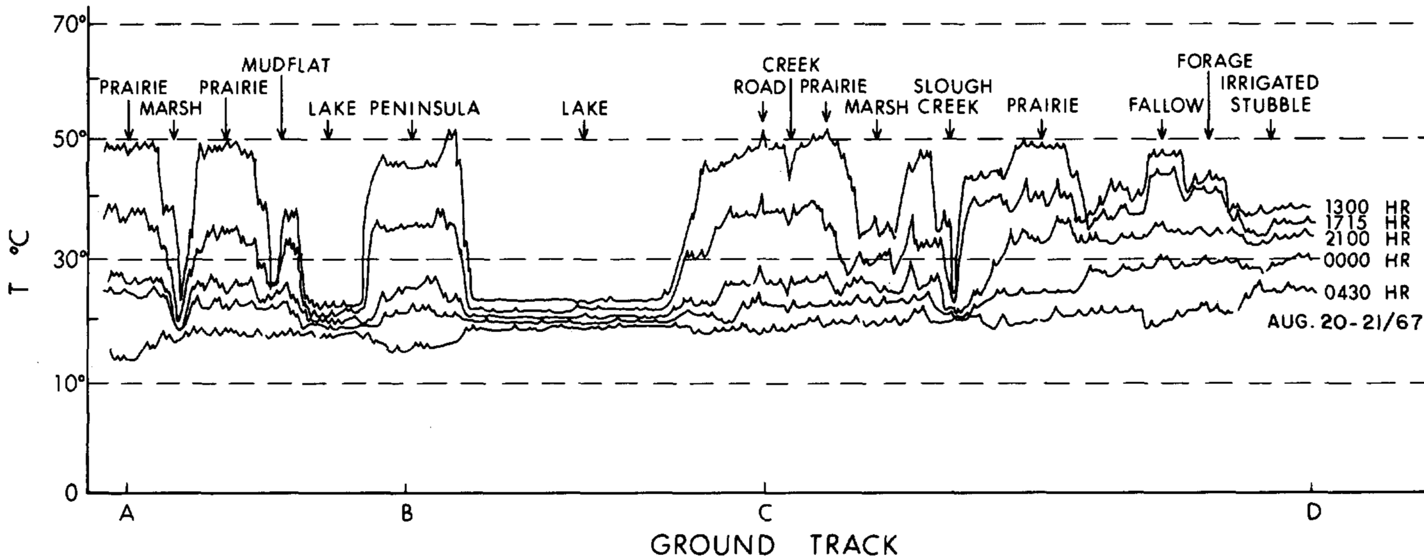

FIGURE 6.—Surface radiation temperature (°C) at various intervals over ground track ABCD of Lake Murray.

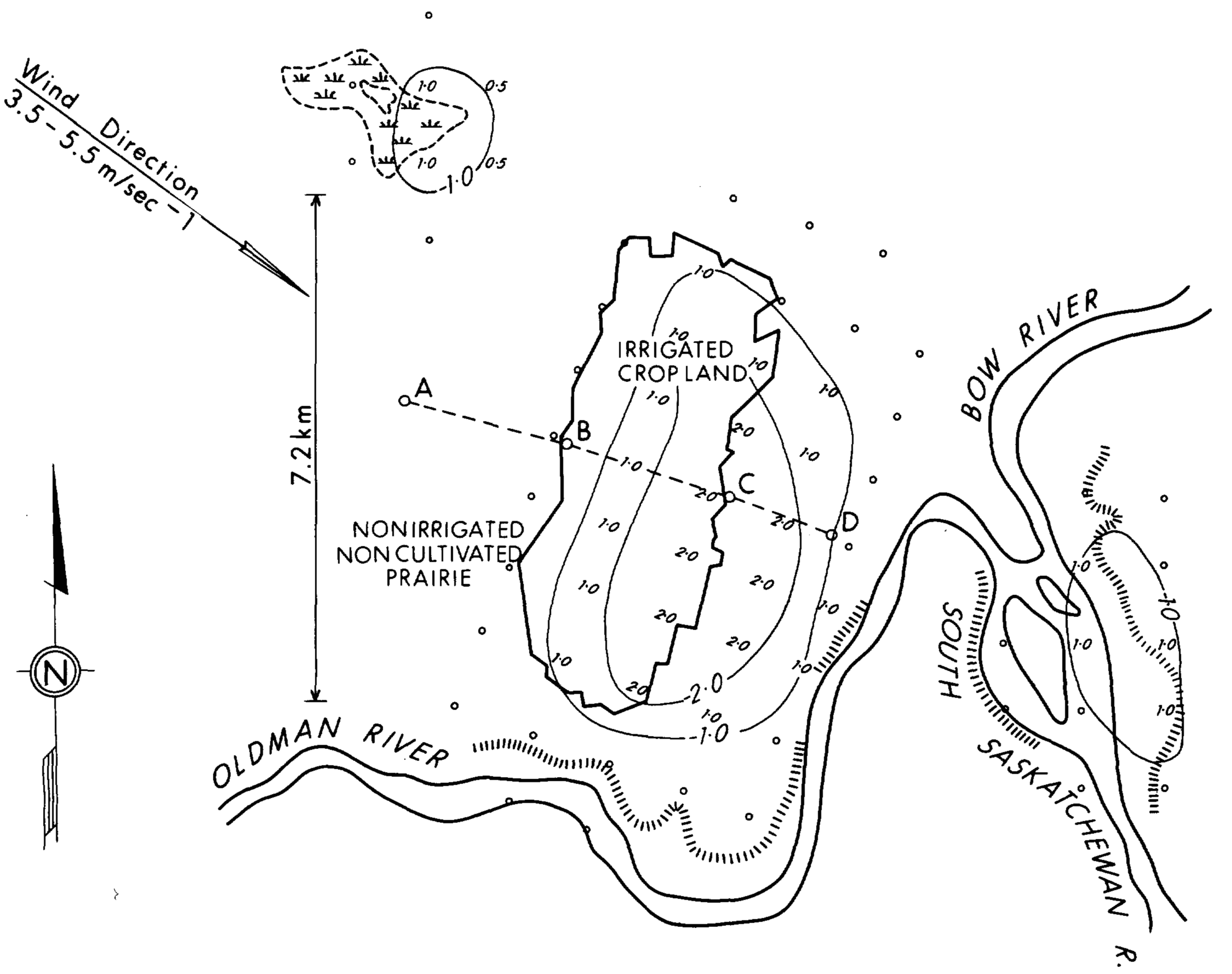

FIGURE 7.—Isotherms and temperature grid of average air temperature difference (°C) between the position indicated at 15 m and ambient prairie air 7 km upwind at the same altitude, near the irrigation project near Bow Island, Alberta, on Aug. 8, 1966, for the period 1200–1500 hr (lat. 49°55′ N., long. 111°45′ W.).

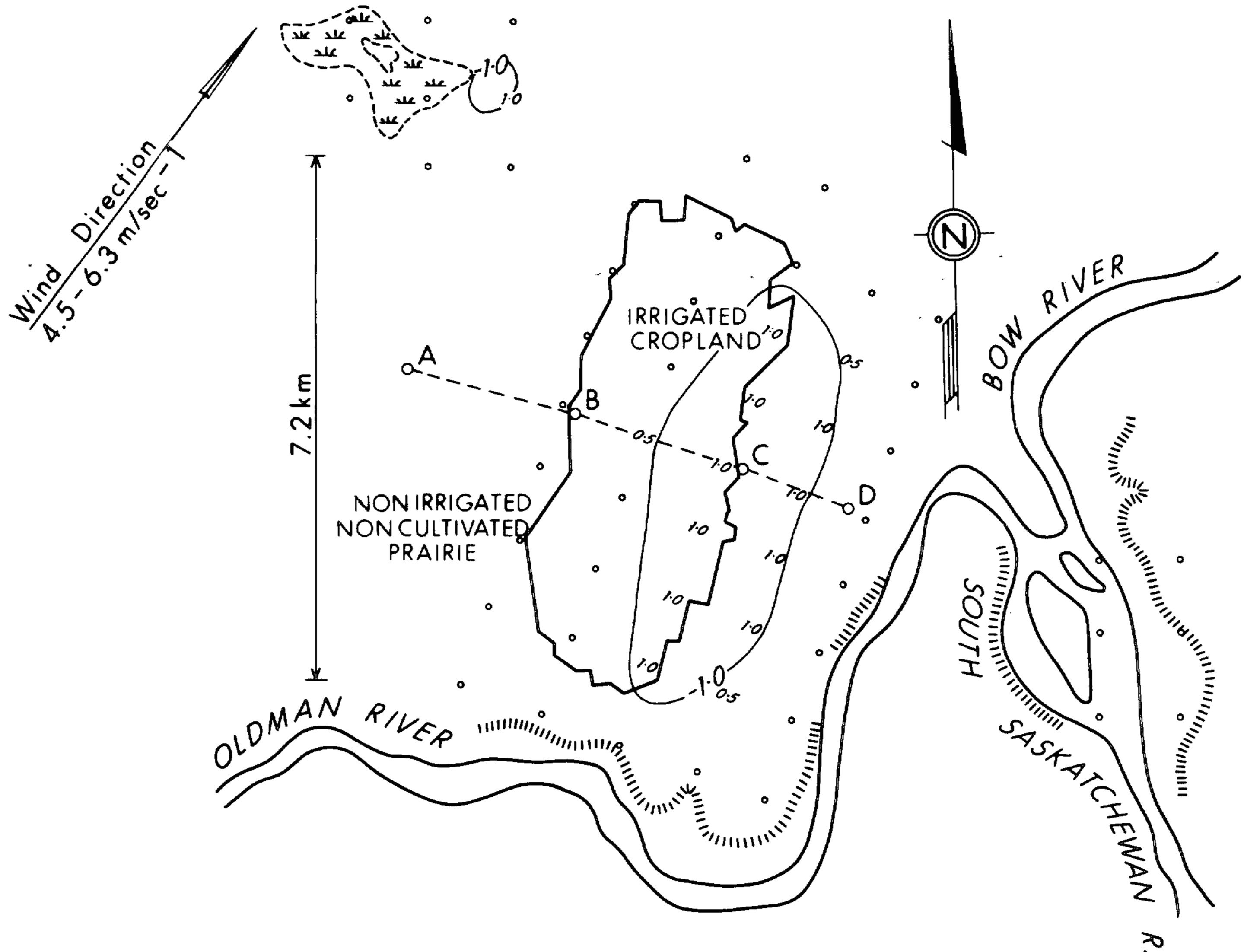

FIGURE 8.—Isotherms and temperature grid of average air temperature difference (°C) between the position indicated at 45 m and ambient prairie air 7 km upwind at the same altitude, near the irrigation project near Bow Island, Alberta, on Aug. 8, 1966, for the period 1200–1500 hr (lat. 49°55′ N., long. 110°45′ W.).

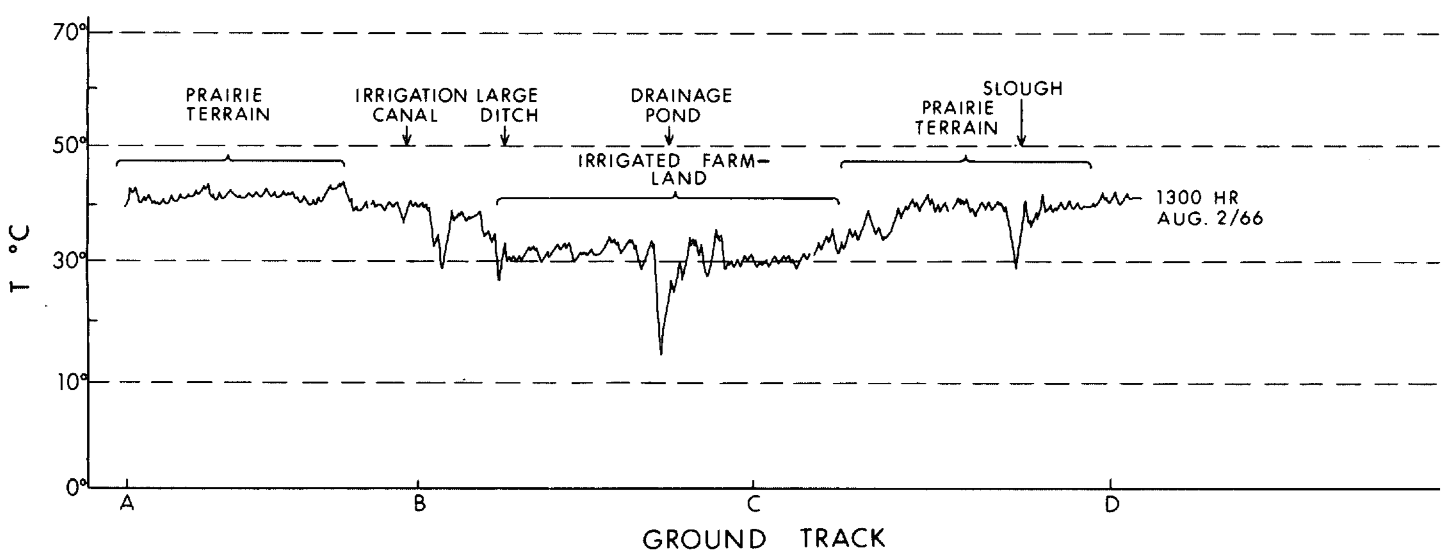

FIGURE 9.—Surface radiation temperature (°C) at 1300 hr on Aug. 2, 1966, over ground track ABCD of an irrigated area near Bow Island, shown in figures 7 and 8.

prairie surrounding the irrigated project is very flat and homogeneous as regards vegetation and surface characteristics for 40 km upwind. The isotherms show temperature differences between the positions indicated and 9 km upwind at the same latitude. The measurements were taken between 1200 and 1500 hr, on Aug. 8, 1966, and show the average position of the cooled air for the 3-hr interval. Wind speed and direction upwind were measured at 15 m.

The day indicated in figures 7 and 8 was exceptional in that cooled air over the district was detectable. However, at not time was cooled air noticed at heights greater than 75 m, or more than 4.5 km downwind from the area. The observations of surface radiation temperature over ground track ABCD (fig. 9) were taken 6 days previous to the air temperatures but they show a temperature discontinuity of approximately 8°C between the irrigated and non-irrigated areas.

The oasis effect of this area was highly dependent on surface heating upwind, wind speed, and wind direction. There are insufficient data at the present time to relate these factors quantitatively. On 60 percent of the days when observations were taken, no effect was measurable. Some air cooling was noted over a small lake approximately 2 km northwest of the irrigated land, and over the junction of the rivers. In view of the explanation given for not being able to relate cooled air to position over Lake Murray, it is somewhat surprising that this was possible over these two, very small features.

SUMMARY

The data presented show that it is possible to measure the effect of small prairie oases on the temperature of the lowest air layers. However, the position of the air cooled by passage over lakes or irrigated areas is highly variable and not always measurable. It seems remarkable that cooled air should persist for the extended periods observed, especially since the air was very unstable at the time. The factors that contribute most to the presence and position of the cooled air are only suggested. Observations indicate that if the effect was measurable at various observational heights over one oasis, then it was measurable over a nearby oasis during the same period; if the effect was absent from one, it was usually absent from the others during the same time period. This suggests a common factor or factors operating at the same time over the geographic area of interest. These factors are doubtless related to radiational heating of the surface (e.g., stability), wind speed, and wind direction. The radiation temperature of the surface around and over the oases shows the sharp contrasts that are possible.

This work points to some of the surface-air relationships that exist on a mesospace and time scale. Further, although the data are not extensive, the results substantiate the view that important information can be obtained about these relationships by using instrumented aircraft. It is envisaged that with the support of ground observations, the complete energy budget of mesoscale areas of the earth can be determined.

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